HIGH-RESOLUTION AIR-QUALITY FORECAST OVER ITALY USING MM5 AND CHIMERE MODELS

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We implemented an Eulerian deterministic modeling system over the Italian domain using the meteorological mesoscale model MM5[1] and the regional chemistry-transport model CHIMERE[2]. The system can be used both in analysis and forecast mode. In forecast mode, the system is typically set up with two nested domains at European and Italian scales (see Figure 1), with simulations starting at 00Z of the previous day (D-1) and ending two days ahead (D+2). An experimental operational service at low-resolution at continental scale is already available on the web (http://pumpkin.aquila.infn.it).

Figure 1. Geographical domain covered by the air-quality forecast system. The larger low-resolution domain (CONT3, 0.5°×0.5°) is used to provide boundary conditions to the nested hi-resolution (up to 5 km) domain over Italy.

Meteorological Input: MM5 setup

We run MM5 meteorological model (version V3-6-1) forced by 3-hourly global forecast fields delivered by NCEP at 00Z of the previous day (D-1). Simulations are nudged toward global forecast using the following coefficients: 10^{-4} for temperature and winds, 2×10^{-5} for moisture. MM5 is run in double-way nesting configuration with a mother domain covering the continental scale domain (see Figure 1) at 36 km horizontal resolution, a first nested domain at 12 km resolution, and eventually a second nest-

1 http://www.mmm.ucar.edu/mm5/
2 http://euler.lmd.polytechnique.fr/chimere/

ed domain at 4 km resolution. In the vertical, the model has 32 terrain-following σ-levels extending up to ~100 hPa, with first 4 layers below 200 m altitude and first 10 below 1 km altitude. The following choices of main parameterizations are adopted:

- Reisner 2 microphysics
- Grell cumulus scheme
- MRF planetary boundary layer
- RRTM radiation
- Noah land-surface scheme

Emissions

Anthropogenic annual emissions at continental scale (0.5°×0.5° grid) for gases (CO, NO_z, SO_x, NMVOCs, and NH_3) and particulate matter (PM10 and PM2.5) are taken from EMEP expert emissions[3] [Vestreng, 2003]. NMVOCs are specieated following Passant et al. [2002] and lumped into model VOC species following the reactivity-weighting procedure proposed by Middleton et al. [1990]. Annual totals are distributed into hourly emission slots using temporal profiles provided by IER. Anthropogenic emissions at Italian scale (up to 5 km) are taken from the hourly emissions inventory developed by CTN-ACE (Italian National Focal Point on Atmospheric Emissions).
Biogenic emissions for isoprene and α-pinene are calculated following Simpson et al. [1999].

Chemistry and Transport processes: CHIMERE setup

CHIMERE (version V200606B) simulates the chemical state (gas and aerosol phase) of a limited region of the troposphere accounting for main processes of chemical emission, transport, transformation and deposition. For our application we use the model in nested configuration with a mother domain covering the continental scale (see Figure 1) at 0.5° horizontal resolution, and one or more nested domains at 10 or 5 km resolution covering Italy. In the vertical, the model has 8 terrain-following σ-levels extending up to 500 hPa, with first levels having an approximate height of 40, 100 and 180 m.

CHIMERE requires in input meteorological data, boundary conditions, land-use information, emissions. Meteorology is provided by MM5 mesoscale model as illustrated above. Boundary conditions are taken from climatological simulations of global models such as LMDz-INCA[4] for gases and GOCART[5] for aerosols. Landuse information is taken from GLCF data base[6]. Emissions are derived from various sources as detailed above.
Main model physical and numerical characteristics are:

- The chemical mechanism (MELCHIOR, Latuatti [1997]) is adapted from the original EMEP mechanism.
- Photolytic rates are attenuated using liquid water or relative humidity
- Boundary layer turbulence is represented as a diffusion [Troen and Mahrt, 1986]
- Vertical wind is diagnosed through a bottom-up mass balance scheme.
- Dry deposition is as in Wesely [1989]. Wet deposition is included.
- Six aerosol sizes represented as "bins" in the model.

3 http://webdab.emep.int/
4 http://www-lsceinca.cea.fr/
5 http://code916.gsfc.nasa.gov/People/Chin/gocartinfo.html
6 http://glcf.umiacs.umd.edu/data/landcover/

- Aerosol thermodynamic equilibrium is achieved using the ISORROPIA model[7].
- Several aqueous-phase reactions considered
- Secondary organic aerosols formation considered
- Windblown dust erosion and resuspension considered
- Advection is performed either by a first upwind scheme, the Van Leer scheme or by the PPM (Piecewise Parabolic Method) 3d order scheme for slow species.
- The numerical time solver is the TWOSTEP method.

Web output

MM5 and CHIMERE operational runs are driven by Linux shell scripts that with all the necessary I/O information. Graphic output is achieved using automatic GrADS[8] scripts. Output on the web is automatically updated on the Apache2[9] server. An example of the web interface is given in Figure 2. The user can access information on the latest forecast in a compact way on all regulated species (PM10, PM2.5, ozone, NO_2, and CO), and also visualize animations clicking on the headers.

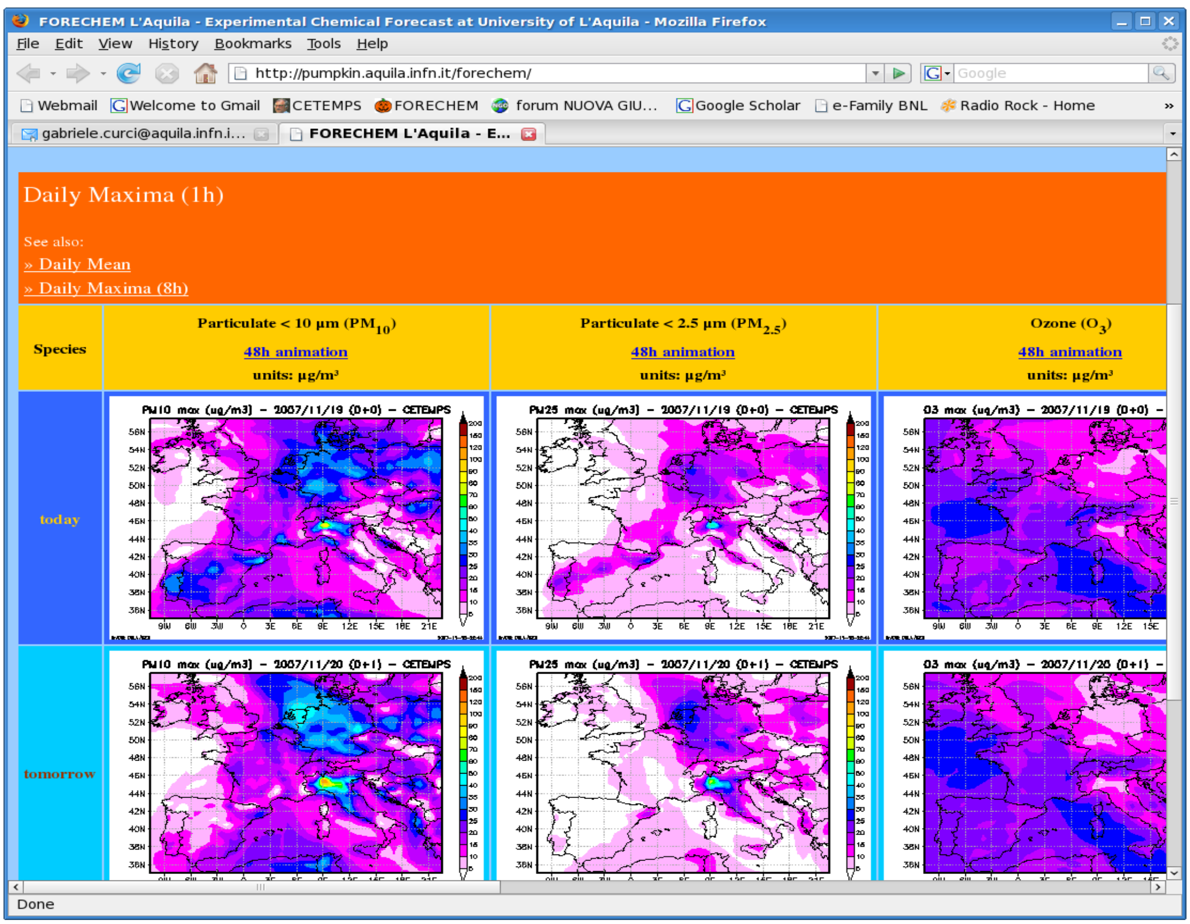

Figure 2. Sample screen of the experimental operational air-quality forecast run at CETEMPS (http://pumpkin.aquila.infn.it)

7 http://nenes.eas.gatech.edu/ISORROPIA/
8 http://www.iges.org/grads/
9 http://httpd.apache.org/

Sample hi-resolution output

The new version of the operational forecast system already under development, will have a much higher resolution over Italy. CHIMERE simulation at continental scale is used as boundary condition for a CHIMERE nested simulation at a resolution of 10 or 5 km, depending on the application. In Figure 3 we show the average surface ozone daily maximum during July 2005 simulated at 10 km horizontal resolution over a domain that covers most of Italy. Very detailed features are visible downwind of main urban agglomerates of the Po Valley, Rome and Naples. In Figure 4 we show some selected hourly ozone timeseries observed at AirBase[10] monitoring sites compared with MM5/CHIMERE simulations at low- and hi-resolution: the latter reproduces better both the maximum values and the observed variability.

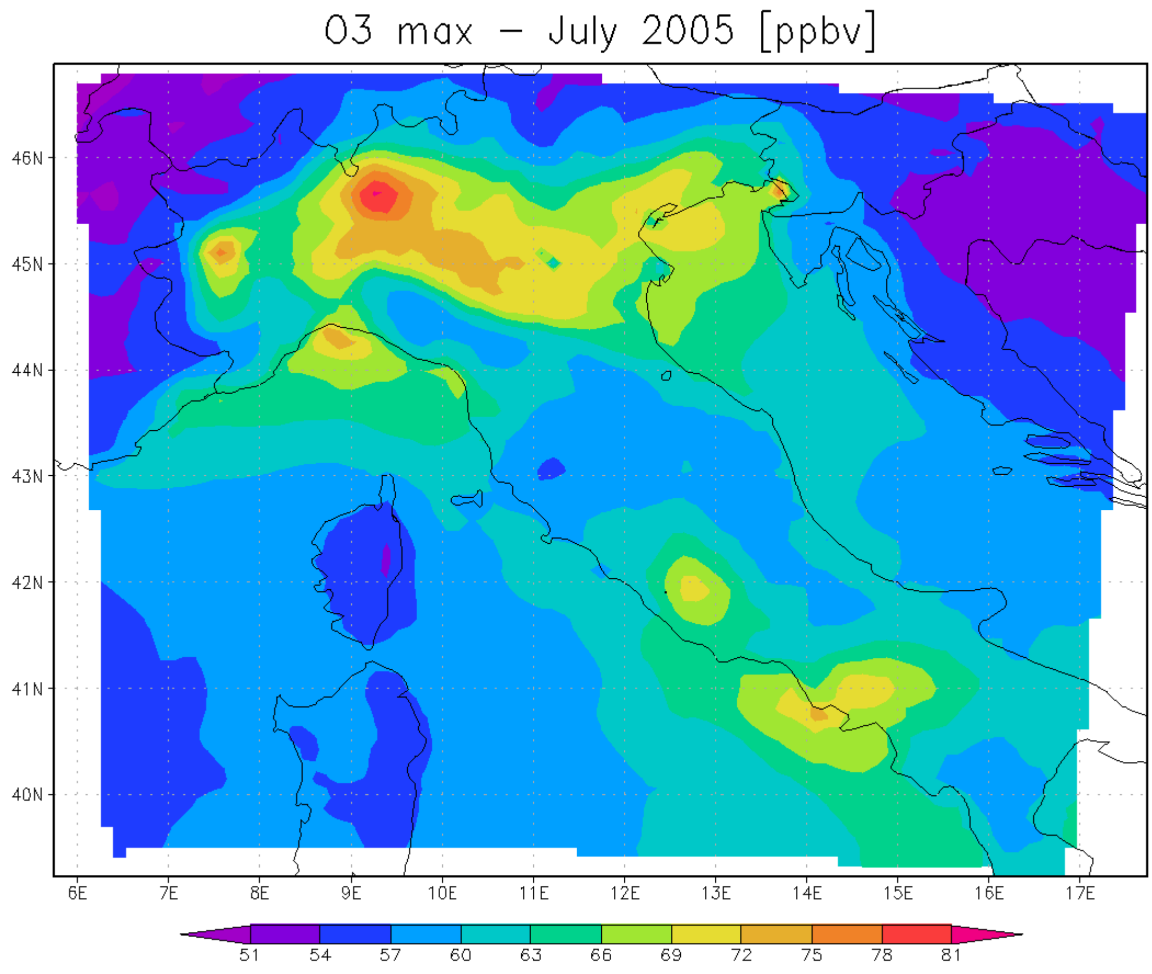

Figure 3. Average surface ozone daily maximum over Italy in July 2005 as simulated at 10 km horizontal resolution using MM5 and CHIMERE.

10 http://air-climate.eionet.europa.eu/databases/airbase/

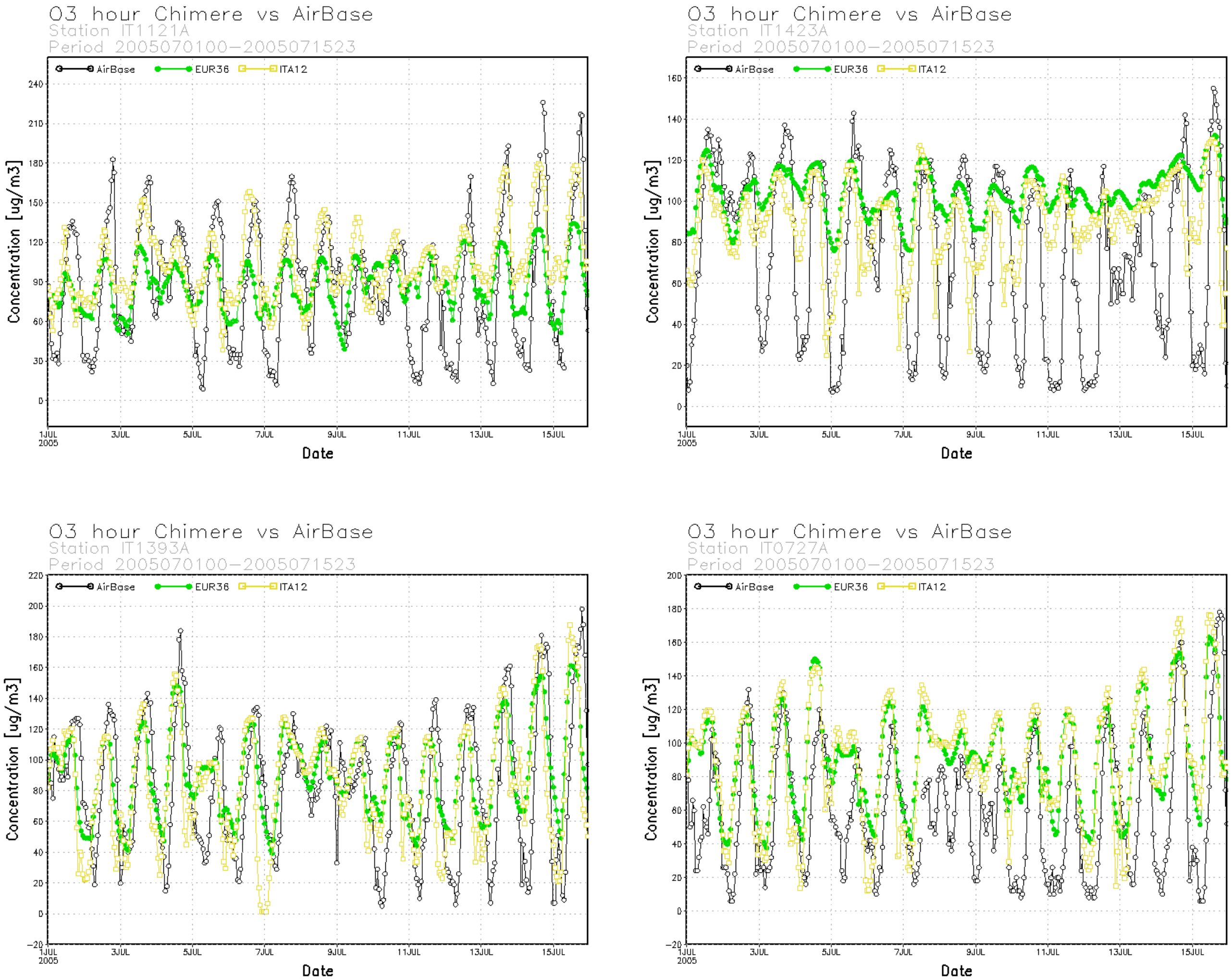

Figure 4. Selected time series of observed hourly ozone at AirBase monitoring sites, and results from MM5/CHIMERE simulations at low- and hi-resolution (EUR36 and ITA21, 0.5° and 10 km respectively). Stations characteristics: top-left) IT1221A: DRUENTO (TO), rural background; top-right) IT1423A: PESCARA, suburban background; bottom-left) IT1393A: MANTOVA, suburban industrial; bottom-right) IT0727A: MODENA, urban traffic.

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